Design of a Reef for Coastal Protection

P. V. Chandramohan

Abstract The beach at Pudussery has been badly eroded. The rock armour placed there to stop the erosion marred the beauty of the beach. An agency was commissioned to go into the matter and suggest remedies. The scheme suggested by them included a reef on the northern side. The three components of this scheme were a raised work area, a rubble bed for a wedge to be installed and a triangular-shaped wedge. The bed is submerged and was designed based on the formulations of Van der Meer. Engineering design of the components had to be carried out before execution. It was decided to use steel for fabrication of the wedge for easiness of construction. The paper deals with the engineering design of the components.

Keywords Reef · Wedge · Submerged structure · Base pressure · Wave force

1 Introduction

Pudussery had been a favourite spot of beach going public for years. But during recent times, the beach at Pudussery started eroding. This went to the extent that there was no beach left for the patronising public. For stopping the onward progress of erosion further into the land, large rock pieces were dumped at the interface with waves. This has slowed down the advance of erosion but intruded into the beauty of the beach. In any case, the beach could no more be patronised as a picnic spot. Please see Fig. 1.

A study was conducted to restore the beach to its original glory. This study was done by M/s Sanctuary beach. After elaborate model studies, they had proposed certain activities to be taken up. One of the recommendations of the study was the formation of a reef at the northern side of the location. This would have reversed the erosion process and would have resulted in beach building.

P. V. Chandramohan (✉)
Navayuga Engineering Company Ltd., Plot 379, Road #10, Hyderabad 500033, India
e-mail: pvcmohan@gmail.com

© Springer Nature Singapore Pte Ltd. 2019

K. Murali et al. (eds.), *Proceedings of the Fourth International Conference in Ocean Engineering (ICOE2018)*, Lecture Notes in Civil Engineering 23,
https://doi.org/10.1007/978-981-13-3134-3_22

Fig. 1 Beach eroded away

2 General Arrangement of Components

The shape of the reef and its components was arrived at by the agency which made the morphologic/oceanographic study. Engineering design of these components was to be carried out before execution. Please see Fig. 2. The reef consisted of three parts. One is the work area to be filled up at the coast. The second is a rock bed about 2 m high to act as bed for a wedge-shaped box. The third is the wedge to be fabricated with steel.

The total length of the reef projecting into sea is 171 m. The work area is 52.75 m from the shoreline into the sea. Its width at the shore end is 108 m and that at the seaward end is 64 m. Top level of this area has been kept at +3.0 m. Please see Fig. 3. On the seaward side of the work, area is a rubble bed for locating the wedge. This bed is triangular in plan similar to the shape of the wedge. Deepest bed level is at −4.5. The shape of the caisson is triangular in plan. But in order to appreciate the 3-D shape, please see Fig. 4.

3 Hydraulic Parameters and Design

Tidal range at the location was given as 1.0 m. A storm surge of another 1 m has also to be considered.

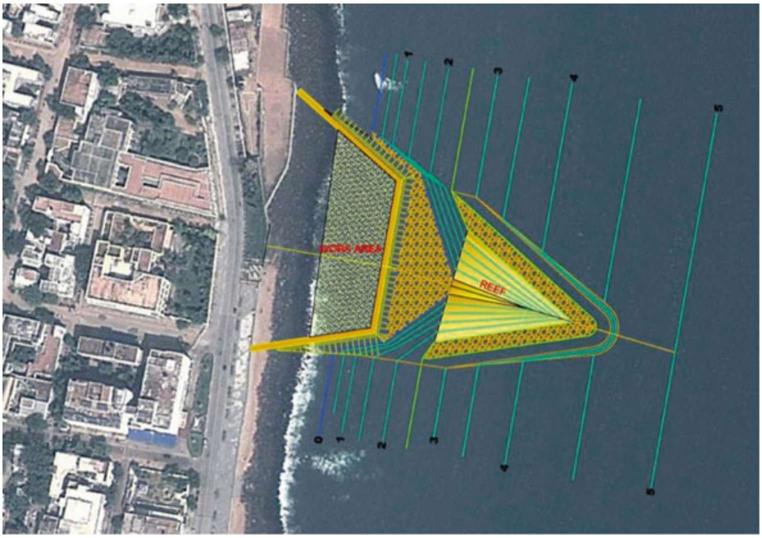

Fig. 2 Layout of the reef

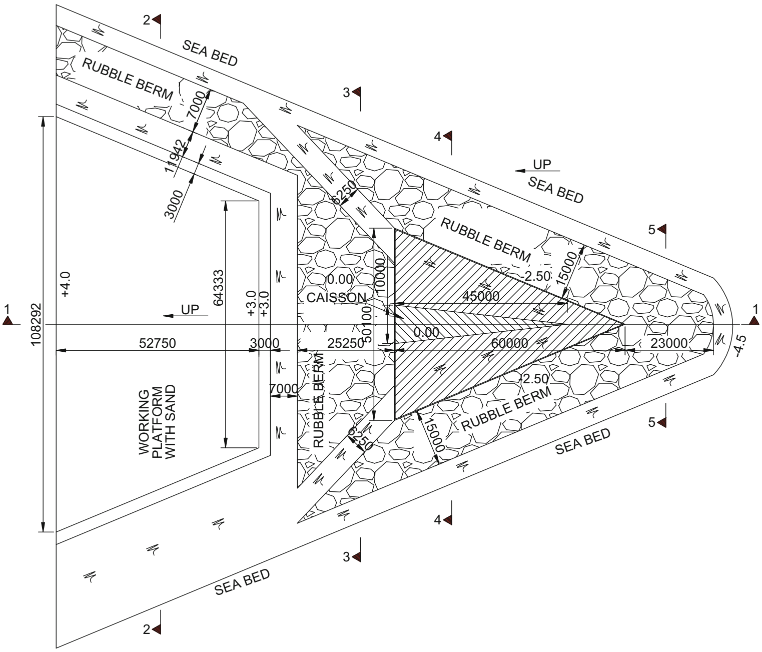

Fig. 3 Components of the reef

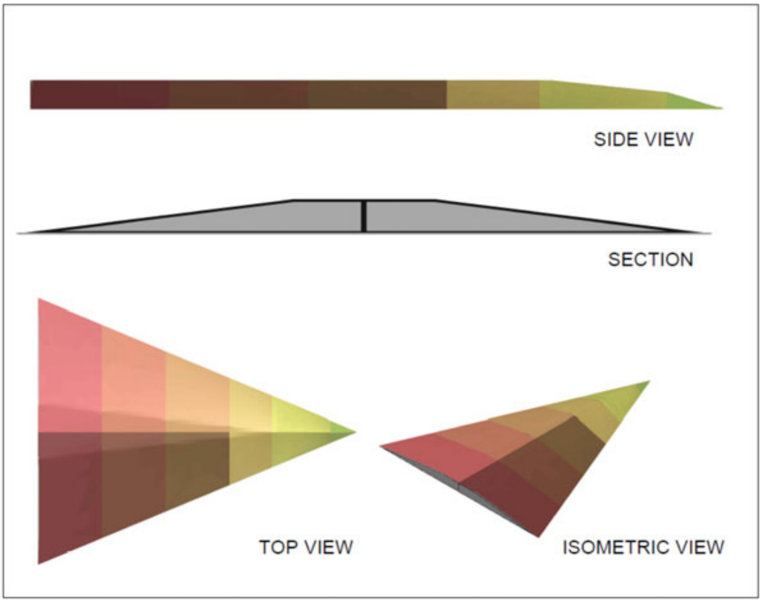

Fig. 4 Shape of caisson

3.1 Work Area

This is mainly a raised platform with soil that has to be retained by a rubble wall. This is located in the surf zone and the top portion of the walls will be acted upon by breaking waves. It is proposed to use rubble mound to retain the soil. The size of the stones was arrived at by Hudson's formula as per Shore protection manual [1]. Since it is very near to the shore, wave heights were small. A stone weight of 500 kg was used.

3.2 Rubble Bed for Wedge

This is a submerged structure. Bed level varies from −4.5 to −1.5. Top of the bed is at −2.5. The low water level is 0.0. This means that there will be at least a water cushion of 2.5 m on top of the bed. In the transition area between the caisson and the work area, the rubble mound has a top level of 0.0. Structures with water cushion are often called submerged structure. Hudson's formula will overestimate the size of stones. Van der Meer provides a procedure for the design of a submerged structure. This has been utilised here. But wave heights vary along the length of the bed as breaking wave heights are governed by the water depth. Breaker height varies with the stage of the tide as well. For example, wave height at high water at a bed level of −1.5 is 2.81 m while that at low water is 2.02 m. Water cushion also varies with

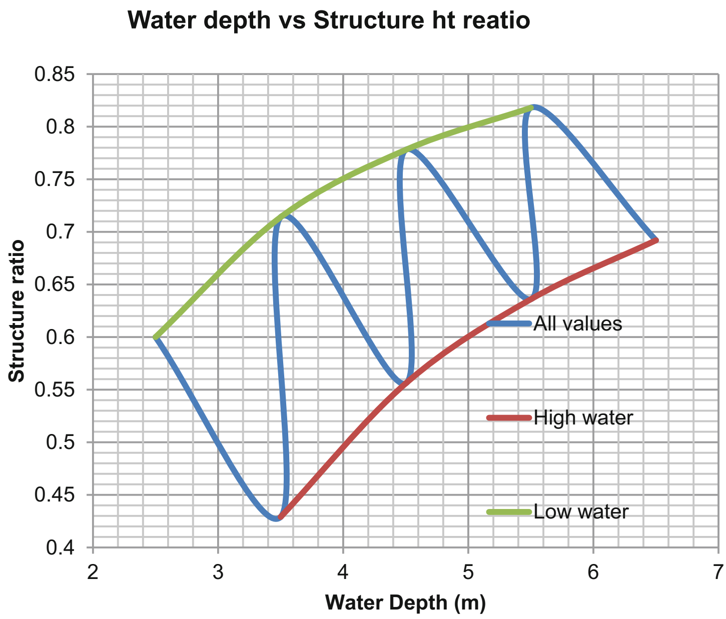

Fig. 5 Variation of structure height-to-water depth ratio

the stage of the tide. So, for doing the design, a computer program was developed. Breaking wave height at high water varied from 2.81 to 5.1 m. Besides, the weight of armour stones varies with the ratio of structure height to water depth. This ratio varies with the stage of the tide as well. Please see Fig. 5. This shows the variation of the above ratio with water depth and also its oscillation with the stage of the tide. Envelopes have been constructed to show the values of the ratio at high water and low water.

Please see Fig. 6. The weight of the stones arrived at by Van der Meer's method is plotted against the water depth. Because of the water cushion present over the structure, wave energy was moderated to minimise the increase in stone weight.

From the above analysis for various wave and tide conditions, maximum stone weight was arrived at as 1.52t. This was provided all through though this could be less on the leeward side.

To get an idea about the effect of submergence on the weight of armour, a graph was plotted for constant wave parameter with varying submergence. Please see Fig. 7. Armour weight goes on reducing with an increase in submergence. This is to illustrate the role of water cushion on stone weight.

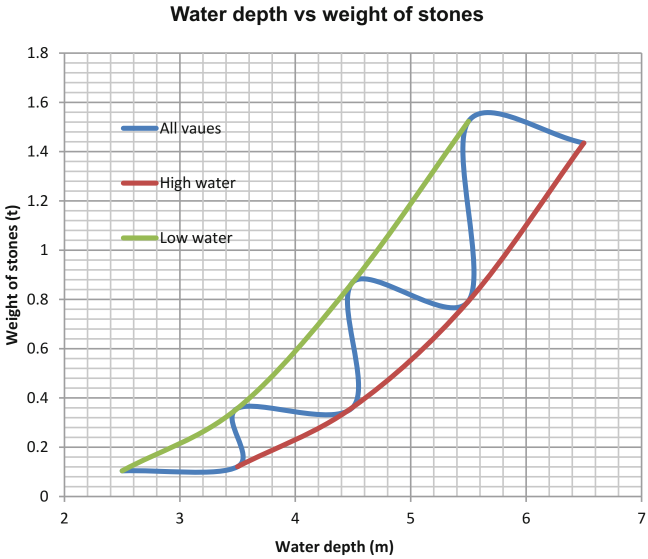

Fig. 6 Variation of stone weight with water depth

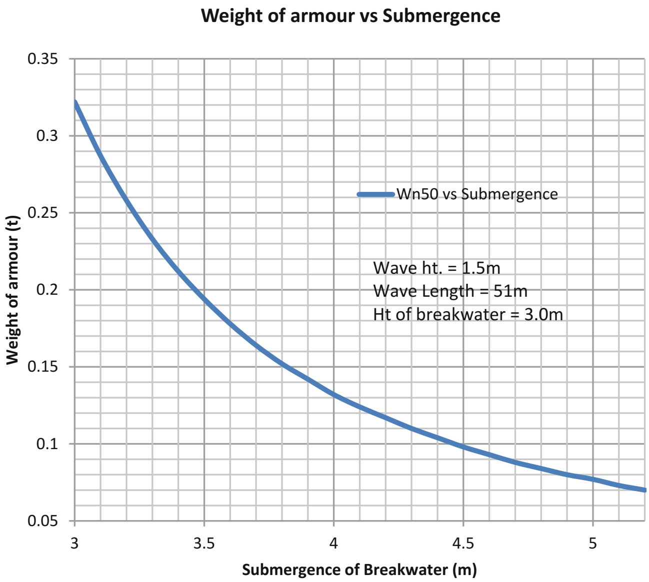

Fig. 7 Effect of submergence on armour weight

3.3 Wedge

As can be seen in Fig. 4, the wedge is triangular in plan. It is triangular in cross section as well. Length of the wedge is 60 m. Its width at the base is 50 m. As mentioned earlier it is triangular in cross section. Height at the apex is 2.5 m. Since the bed is at −2.5, the apex will be at 0.0. Initially, it was decided to make it as concrete caisson that could be floated out into position. But this posed problems in handling and flotation. So, the material was altered to steel. Please see Fig. 8 for the general arrangement of the wedge on the bed.

Please see Fig. 9. Various sections of the wedge are shown. The wedge will always be under water.

Externally it will be acted upon by wave forces like a submerged structure. The structure is taken as being acted upon by waves from one side. Breaking wave formulation by Takahashi et al. [2] was used to quantify the pressures and forces. The original formulation was for an exposed structure. This was slightly modified for a submerged structure. Besides, the pressures had to be reduced to an inclined surface. This was done using the formulation given in the Shore Protection Manual. It may be noted that the side angle of the wedge is only 5.71°. This is almost equivalent to a beach slope. So, the resultant horizontal forces were found to be much less. One salient feature of the force configuration is that the wave force acts only on the seaward side.

Please see Fig. 10. Because of the flat angle of 5.71°, vertical forces were predominant. To resist the forces, 25 mm thick steel plates were used. Longitudinal stiffeners were provided at a spacing of 1.5625 m c/c, and cross stiffeners were provided at 1.875 m c/c. These plates were analysed based on the provisions of IS: 5620–1985 Structural design criteria for low head slide gates [3]. Stresses in the skin plates were limited to 99.26 MPa against 140, allowable. Stiffener beams were also made of plates and stresses were limited to 56 MPa.

Stability of the wedge against external forces was investigated. Since forces on the leeward side were predominant, the overturning moment is towards the seaside. But as the base width is very large, 50 m, factor of safety against overturning came

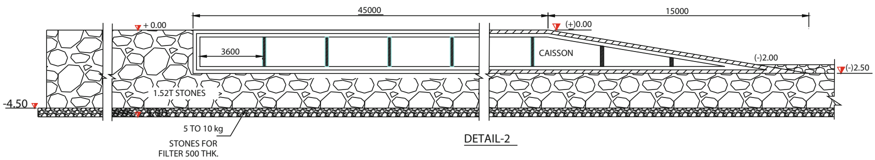

Fig. 8 Position of the wedge on the bed

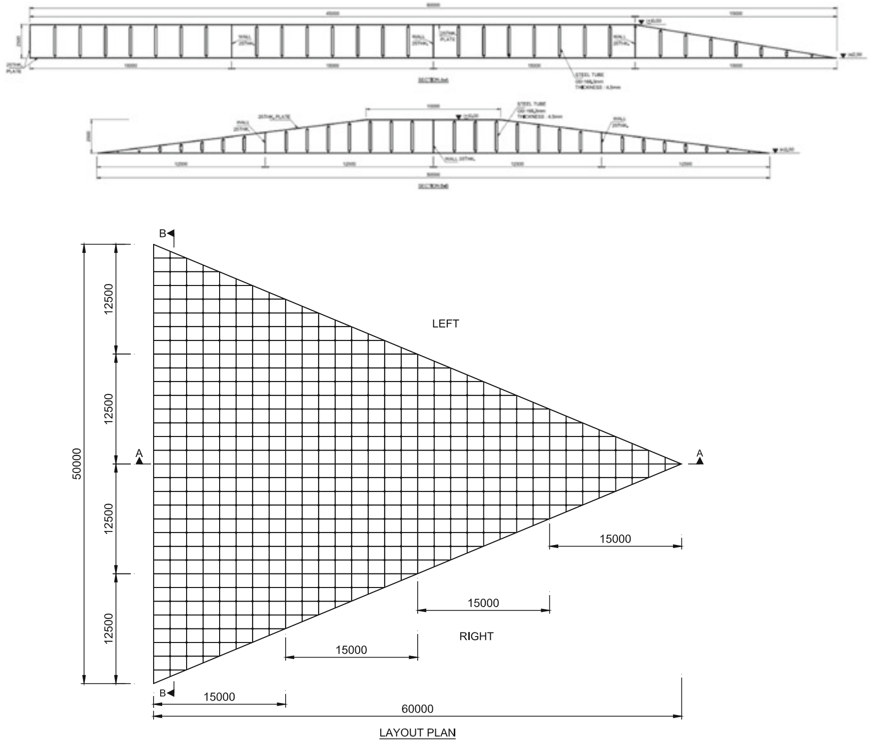

Fig. 9 Sections of the wedge

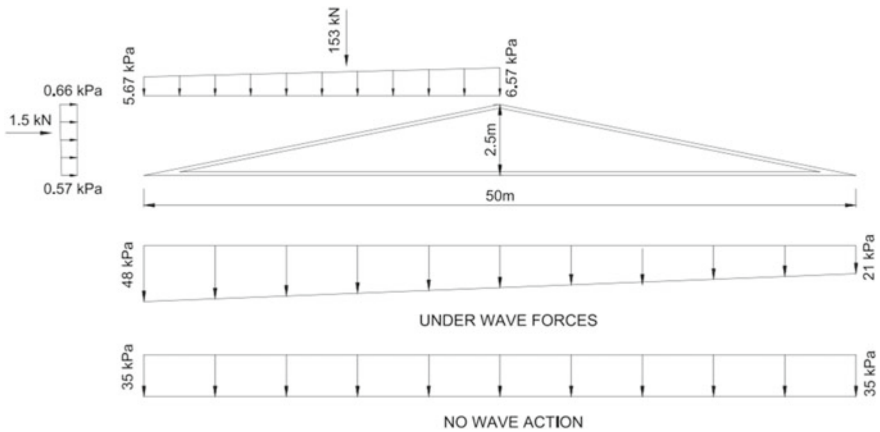

Fig. 10 Forces and base pressures on the wedge

out to be 7.6 and that against sliding, 567. As can be imagined bearing pressures at the base were very low. Two conditions were investigated. One is when the object

Fig. 11 Progressing with the work area

is subjected to wave action from the seaside and the other, when there is no wave action. The base pressures are given in Fig. 10. Total weight of the wedge came to 737t.

4 Present Position

Construction of the work area is in progress. Please see Fig. 11. This component is critical as fabrication of the wedge is to be carried out on this platform. After fabrication, the proposal is to slide the empty wedge down on to the wedge. Top of the work area is at +3.0 and will be above water level. It has to be installed at a base level of −2.5 under water. The project is slated to be completed within a few months.

5 Conclusion

The shape of the reef was arrived at by model studies by morphologists/oceanographers. The task of the engineers is to design the various components of the scheme and implement it at the site. Constant interaction with the proponents was necessary during the design stage in order to achieve the desired results. One important point was that the work had to be carried out in marine conditions. Most of the components were located under water. The design had to take into account the construction aspects and had to be modified to suit the construction requirements. Changing over from concrete to steel was one such requirement.

References

1. U.S. Army Corps of Engineers (1984) Shore protection manual, pp 7–175
2. Takahashi, Tanimoto, Shimosako (1990) Wave and block forces on a caisson covered with wave dissipating block, Report of Port and Harbour research institute, Yokosuka, Japan, vol 30, no 4, pp 3–34 (in Japanese)
3. Bureau of Indian Standards (1985) IS: 5620–1985 Recommendations for Structural design criteria for low head slide gates